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DIMENSIONS NBS

REDUCING FIRE LOSSES

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CONTENTS

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Cover: Current fire losses approximate 12,000 deaths and almost $3 billion in direct property damage annually in the United States. The goal of the NBS fire program is to develop the technical base for the standards and specifications needed to reduce these fire losses by 50% over the next generation.

The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:
The Institute for Basic Standards
The Institute for Materials Research
The Institute for Applied Technology
The Institute for Computer Sciences and Technology
Center for Radiation Research
Center for Building Technology
Center for Consumer Product Safety

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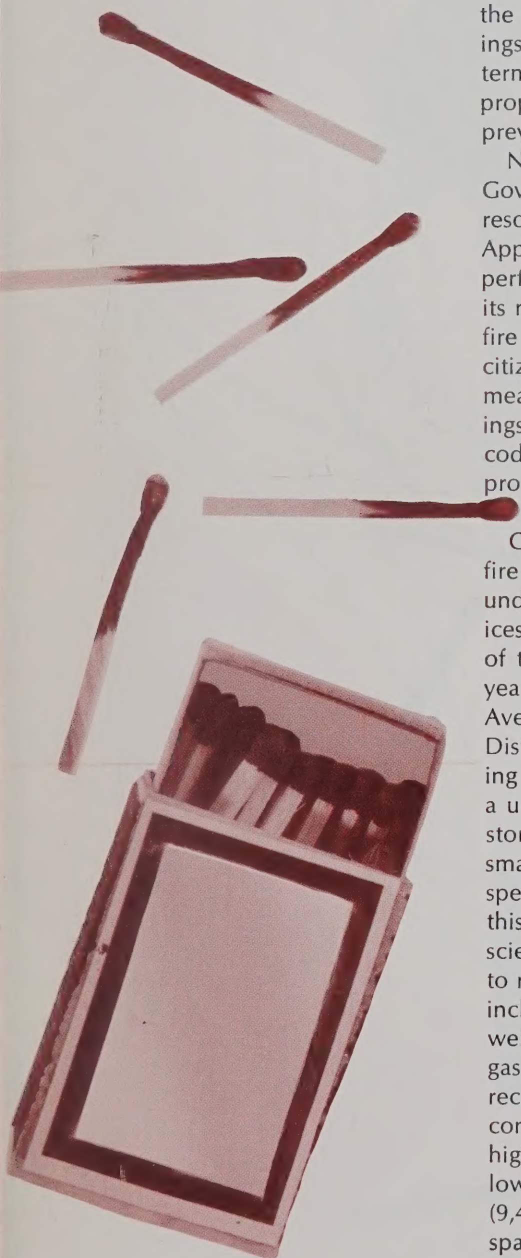
NEW FIRE RESEARCH BUILDING

THE National Bureau of Standards has a new building on its Gaithersburg campus designed to "consume" corridors, apartments and nursing home rooms in flames.

Don't misunderstand. NBS is not in the business of burning down buildings. It *is* dedicated however to determining why and how fires start, are propagated and how they might be prevented.

NBS' Fire Program is the Federal Government's primary fire research resource. Located in the Institute for Applied Technology, the Program performs numerous tests as part of its research on structural and product fire performance. To the average citizen, the result of NBS' fire research means safer, more fire-resistant buildings through improved building codes. It also means safer consumer products, such as flame-retardant sleepwear for children.



Central to this mission is the new fire technology building constructed under auspices of the General Services Administration at the south end of the NBS campus. It replaces a 59-year-old test facility at Connecticut Avenue and Van Ness Street in the District of Columbia. The new building houses a fire-endurance furnace, a unique corridor-test facility, a two-story high "smoke" room and a smaller fire room as well as other special-purpose testing equipment. In this highly instrumented building, NBS scientists and engineers will be able to record the numerous effects of fire including temperatures, radiation, weight loss, velocity and smoke and gas concentrations in a central data recording room. The building, which consists of a 10.5-meter (35-foot) high bay and a 7.2-meter (24-foot) low bay, contains 873 square meters (9,400 square feet) of assignable space.

The new fire-endurance furnace, which employs premixed gas-air burners, replaces three furnaces used at the old site. It will be used for fire endurance studies of load-bearing walls, partitions and columns up to a maximum of 18 tonnes (20 tons). In addition the new furnace will have the capability—not contained in any of the older furnaces—to test a combination floor-wall assembly. This capability will enable NBS researchers to test the sometimes critical joint between the ceiling and the wall.

Another unique feature of the new furnace is that it will be possible to adjust for positive and negative pressures. Pressure has an important effect on the way various materials and structures hold up in a fire. Pressures from minus 1.2 to plus 3.8 millimeters (minus .05 to plus .15 inches) as measured with a water column will be attainable. The furnace has a special smoke abatement after burner to conform to strict Federal and local air pollution requirements.

The 12-meter-long (40-foot) burn corridor is the largest of its kind. It will be used to test flame and smoke propagation in a variety of corridor settings. The width of the corridor will be adjustable from 2.4 to 3.6 meters (8 to 12 feet). A room off the corridor will serve as an ignition point. It will contain combustible materials to resemble the fuel loading found in an apartment, nursing home or hospital room. There is a crawl space beneath the corridor floor, and a series of access holes in the floor to permit installation of improved instrumentation.

The burn corridor will terminate at a hood where smoke and gaseous combustion products will be sucked into the building's main smoke abatement system. Observers and photographers will be able to record the fire's progress through windows along the corridor wall and through a glass partition at the end of the corridor. Photography, both movies and stills,

turn page

is an integral part of the data collection for these tests.

The corridor facility is unique in that NBS researchers will be able to provide air of controlled temperature and humidity at fixed rates down the corridor. This permits the researchers to examine, in a systematic way, the effects of air flow on the propagation of fire.

The "smoke" room in the new building measures 6 by 6 meters (20 by 20 feet) and will be twice as large as the previous one. It will permit the fire testing of a fully furnished room providing a more authentic picture of potential flame spread in a residence. Smoke detectors, sprinklers and other devices may be used here to develop data suitable for use in drafting performance criteria.

The building will also house a 4.8- by 6-meter (16 by 20-foot) fire room. This chamber will be used to test-burn individual pieces of furniture and equipment such as tables, chairs and curtains. This room, as well as all other test equipment in the building, is vented into the smoke abatement system.

The main smoke abatement system features a 15-meter-high (50-foot) smoke stack able to suck in 240 cubic meters (8,000 cubic feet) of smoke-laden air each minute. The smoke will be brought to the stack through an elaborate hood and ducting system with interlocking dampers.

The stack—2.4-meter (8-foot) diameter at the bottom—is lined with fire brick and contains a gas-fired burner to burn the smoke at 760 °C. The design is to provide strict adherence to air pollution standards.

What about fire protection in the building itself? Walls outside of test areas have standard 1-hour fire endurance ratings; those in the test rooms, mechanical equipment room and data room are of 2-hour fire endurance. The building is equipped with heat and smoke detectors and has water standpipes strategically located.

In short, the National Bureau of Standards has tried to make this new facility, which cost $1.3 million to construct and equip, the most advanced fire-test center in the Nation. It is designed to assist NBS in meeting its objective of making citizens less vulnerable to loss of life and property from fire. □

NBS' new fire technology building.

A LOOK AT FIRE RESEARCH

*Dr. John W. Lyons**

UNWANTED fire reaps a grim toll in the United States. Each year more than 12,000 of our citizens die in fires and several hundred thousand more suffer serious burn injuries. A severe burn is the most traumatic insult the human body can sustain; treatment and recovery are painful and lengthy, often including repeated surgical procedures. In addition, property damage drains some $11 billion from our economy.

These figures, stark in themselves, are all the more shocking when they are contrasted with figures from other industrialized countries. For example, Japan reports 0.61 fires for each 1,000 persons as compared to 13 for the United States. Japan has 2.88 fire deaths for each million persons *vs* 57.1 in the United States. Figures can be recited for several European countries to the same effect. While the statistical basis for these figures is less than perfect, the unfavorable position of the United States seems beyond dispute.

Why does our Nation have such a

turn page

* Dr. Lyons is the Director of the Fire Programs at the National Bureau of Standards.

high percentage of fire loss? While many of the reasons are not well defined, some factors contributing to the loss can be identified. Our homes are generally of wood construction, as compared, for example, to the stone and concrete commonly used in Western Europe. Our living and working places are replete with plush furnishings. And there is some correlation between energy consumption and fire incidence. Another important factor is the attitudes people have: in the United States we view fire as a misfortune or an unavoidable accident, while the Japanese consider having a fire a felony.

Solving the Problem

The National Bureau of Standards has been the Nation's fire research laboratory for almost five decades. Our laboratory facilities for fire research are among the best anywhere. The NBS staff cooperates closely with the individuals and groups at home and abroad who are working to decrease fire losses. The fire departments, the Congress, various universities, the program on Research Applied to National Needs at the National Science Foundation, the National Fire Protection Association, building code officials and voluntary standards organizations share with us the challenge to make our environment safer.

We are just now gaining a measure of quantitative understanding of fire phenomena. Fire technology is moving slowly from childhood to adolescence. It is a long way from being a mature science. Nevertheless, action on fire cannot wait for a total understanding of the appropriate physical and chemical phenomena. The world demands, now, criteria for controlling fire hazards and recommended practices and procedures. Therefore, interim solutions are required.

Despite the fact that unwanted fires are complex phenomena with cause and effect poorly understood, simplistic solutions abound. Some call for intense public education as the only answer, on the assumption that most fires are caused by people. The flaw is that much of this human behavior is uncontrollable, for example, that of infants, the very old and the mentally deficient. And the victims of this behavior may be other, innocent persons asleep in neighboring rooms. We must deal with the problem on the assumption that accidents will happen.

Others believe that additions of devices such as automatic sprinklers to all occupancies will solve the fire problem. With today's technology and the difficulty of retrofitting existing buildings, this by itself is an impractical idea. What is needed is a balanced approach. At NBS, the fire program is balanced so that effort is applied to ignition prevention, control of fire spread and growth (given an ignition), early warning devices, automatic suppression, building systems to provide for life safety and technology for better methods for the fire services to use in extinguishing fires. Life safety is the overriding concern underlying this approach.

New Projects

Recently two new programs have been created at NBS. One is on furnishings; the other is concerned with fire-control systems. There are few relevant standards on the fire-worthiness of furniture in the house or the office. The contribution of furnishings to fire spread and growth and to formation of smoke and toxic gases is under study in this program with the objective of drafting proposed standards and recommended practices for these products. The second new program focuses on fire-control systems and stresses the development of technology for early warning devices such as smoke detectors, for new and improved uses of automatic sprinklers and for systems to control smoke movement in large buildings. This program, too, is expected to produce draft standards and practices.

These new programs complement the older, existing efforts on materials of construction, building fire endurance, ignition prevention (primarily in consumer products such as apparel, mattresses, carpets and the like) and new concepts and devices for the Nation's firefighters. All this is undergirded by a vigorous program on the basic science of fire—chemistry and physics, fluid mechanics, scaling and modeling and so on. The programs draw heavily on other parts of the Bureau where there are vast resources of basic expertise that apply directly to the needs of the fire effort. We have a substantial information program on fire subjects, including critical analyses of hazards present, from a data base assembled from fire investigations conducted for us.

Using Research Results

Findings of NBS research are presented by the Bureau or the Commerce Department to other government agencies — the Consumer Product Safety Commission; the Department of Housing and Urban Development; the Department of Health, Education, and Welfare; the Department of Defense; the Veterans Administration; the Department of Transportation—for use in setting up specifications. Although neither NBS nor the Department of Commerce have regulatory power, draft standards are submitted by the Bureau to various voluntary standards groups such as the American Society for Testing and Materials, National Fire Protection Association, the American National Standards Institute and the International Standards Organization. Through the Center for Building Technology, communications are readily made to building codes groups and to the building industry.

The research into fire at the Bureau is done with one thought in mind—to reduce deaths and injuries from unwanted fires. Through new technology developed here, new standards and specifications will enter into the Nation's economic and governmental systems that will, one hopes, eliminate many fire risks from our environment. □

NBS RESEARCH GOES BACK MORE THAN 70 YEARS

FIRE research, like fire itself, is not restricted by geographic or jurisdictional lines, nor does its chronicling lend itself to administrative convenience. That is why a neatly packaged history of fire research at the National Bureau of Standards is hard to come by. The subject has been part of NBS activities from the Bureau's earliest years.

There are many facets to fire research: chemistry and physics, economics and government, behavior of people, materials for design and construction, electric wiring and insulation, life safety systems for notification and evacuation of people, communication systems and screw threads. . . .

Screw threads? Standards for screw threads were an obvious area of interest for the country's central standards laboratory, but a metropolitan disaster early in 1904 coupled "screw threads" and "fire" in a significant way.

Screw threads and fire were coupled because firehoses often could not be. Because of this, Baltimore suffered a calamitous February fire that in two days gutted 2,500 downtown buildings worth $50 million. Engine companies from nine neighboring cities responded to the emergency but after arriving on the scene had to stand by helplessly because their hoses could not be coupled to each other and would not fit Baltimore hydrants.

Baltimore's disaster initiated a project at NBS to collect and evaluate firehose couplings. A total of more than 600 varieties of couplings was collected from all parts of the United States. In 1905, NBS and the National Fire Protection Association selected a coupling which could serve as a national standard, together with an adaptor for non-standard couplings.

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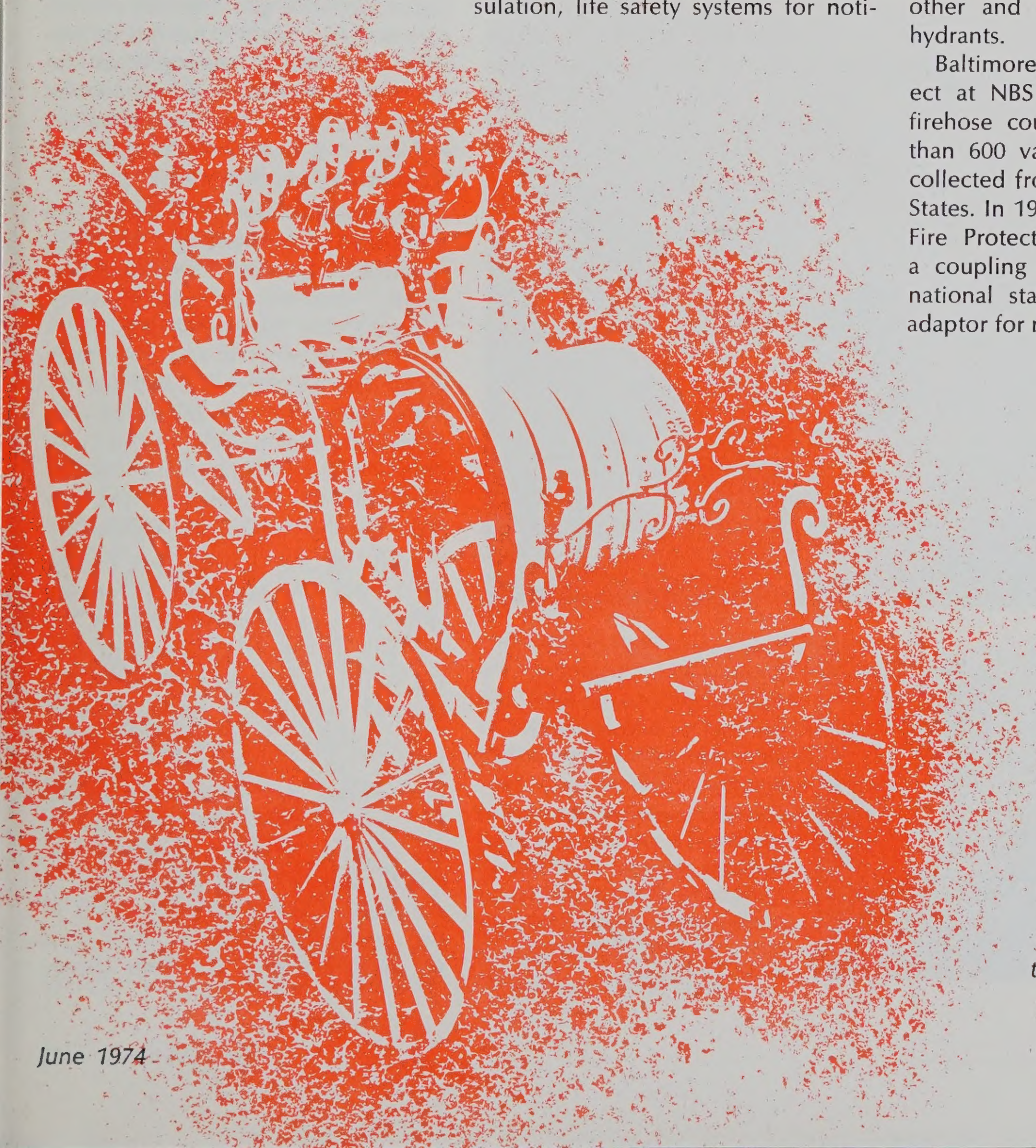
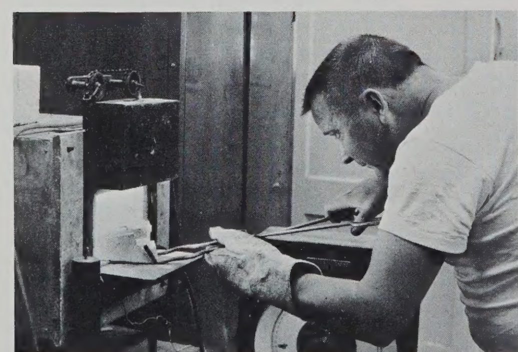


This ancient equipment resembles apparatus in use when the Bureau began its research in the early 1900's.

In 1928, NBS conducted a unique full-scale burnout test in two downtown Washington, D.C., buildings that were ready for razing. The results helped to shape modern building codes.



Getting the "feel" of a writhing hose by actually fighting a fire, these NBS specialists participated in a University of Maryland Basic Fireman's Course.

NBS researcher places specimen container and firebrick support in muffle furnace for firing, part of a procedure for measuring potential heat of materials in building fires.

70 YEARS *continued*

Eight thousand cities and towns remained to be convinced of the advisability of undertaking the expense and readjustment necessary to convert. About 400 took action in the next dozen years. By 1924 sufficient progress had been made for the American Engineering Standards Committee to publish an American Standard for screw threads in firehose couplings. But a "100 percent standard" municipal posture on firehose couplings has not yet been achieved, and some fire losses still result from incompatibility of equipment.

The NBS role in this and other aspects of fire safety and research was typically down-played in the Bureau's annals. The 1904 annual report, for example, touches on the question of a uniform system of firehose couplings as "among other important matters which have received attention" in a brief reference at the end of a section on "Engineering Instruments and Materials."

Appearing in the 1914 annual report was the subheading, "The Fire-Resisting Properties of Structural Materials." That was the year in which Congress first earmarked $25,000 a year for NBS work in this area. Congress also provided $15,000 for research into "the best means of protecting life and property from lightning"—research which the Bureau performed in cooperation with the National Fire Protection Association.

Much of the activity was carried on in the Thermometry, Pyrometry and Heat Measurements Division, but the annual report pointed out that the subject was too broad to be encompassed within a single division. "The problems relating to the preparation and testing of concretes, tiles, bricks, steel structural material, etc., are receiving the attention of the concrete, ceramic, structural materials, and chemical laboratories of the Bureau; the electrical features of the investigation, such as safety rules for electric wiring, problems apper-

taining to the national electrical code, etc., are being looked after by the electrical division, while the behavior of these materials under heat as to their expansion, etc., is being investigated by the division of weights and measures."

All the interrelated studies, the report noted, provided "an excellent illustration of the broad scope of an engineering investigation that requires the cooperation of nearly every one of the scientific and engineering laboratories of the Bureau."

Also cited in this account were studies of the behavior of steel and cast-iron building columns under fire conditions and experiments with various kinds of fireproofing systems. Plans were outlined for collecting and comparing municipal building codes for insights into "those questions on which there are radical differences of opinion." Such investigations were logical extensions of work that had begun in 1910, when insurance industry organizations and NBS set up joint studies of building column performance under fire conditions.

The Bureau's first five decades of fire research were conducted under the provisions of the original NBS legislation of 1901 that called for "the testing and calibration of standard measuring apparatus . . . (and) the determination of physical constants and the properties of materials . . . ."In 1914, the act was amended, authorizing NBS to study the fire resistance of building materials. In 1953, after a rash of deaths and disfigurements from 'torch" sweaters and other highly flammable apparel, Congress passed the Flammable Fabrics Act establishing the first mandatory Federal standard in this field. A 1967 amendment strengthened the standard-setting power of that act by directing the Secretary of Commerce to determine needs for new standards dealing with "unreasonable" fire risks arising from current conditions and materials.

Since then, NBS has served as the Secretary's technical arm in developing standards for carpets and rugs, children's sleepwear and mattresses. The Bureau continues providing this technical backup, now channeled through the new Consumer Product Safety Commission. Currently, this involves further work on children's and adult's nightwear, shirts and blouses, dresses and trousers and interlaboratory evaluation of a cigarette ignition test developed by NBS for upholstered furniture.

A broader mandate was provided by the Fire Research and Safety Act of 1968, amending the Bureau's organic act to delineate a very far-reaching set of responsibilities:

> To provide more effective measures of protection against the hazards of death, injury and damage to property (by fire).

This comprehensive mandate calls for investigation of fire accidents, research into the causes and nature of fire, development of fire prevention, fire control, and death and injury reducing techniques, as well as educational programs, fire information reference services, training programs for the fire services and demonstration projects in support of fire prevention, fire safety principles in construction and improved fire services. In a related move, the Federal Fire Council was transferred to NBS by executive order.

Even so brief a chronicle as this, with its arbitrarily selected highlights, may serve at least to suggest the range of expertise and the richness of experience that the Bureau brings to the problems of fire safety. New and challenging materials and conditions are continually being developed by our high-technology society. These changes mean the lines of inquiry must become even more sweeping—from questions of what the well-protected fireman will wear (helmets, turnout coats, face masks and so on) to how the ordinary citizen can be made secure, whether at home, in a high-rise office building, travelling the highways, waterways or airlines or working in the mines. □

Of the many NBS milestones that have marked the way to a new era in fire research and safety, only a few can be cited here:

1911-12—NBS calibrates fire extinguishers for other agencies, tests and reports upon a new type of fire extinguisher to the Treasury Department.

1917-1920—NBS conducts 106 fire tests to study the fire performance of concrete columns when exposed to fire.

1918—NBS publishes booklet on *Safety for the Household,* devoting an entire chapter to fire hazards.

1933—NBS publishes research paper on fire tests of theater proscenium curtains.

1936—NBS publishes letter circular on flameproofing of textiles.

1942—NBS publishes "Fire Resistance Classification of Building Constructions," summarizing research results for use by building and code officials.

1950—To help eliminate static electricity explosion hazards in industry and in hospital anesthesia rooms, the Bureau furnishes technical assistance to a Federal interdepartmental committee.

1951-1962—NBS published work suggesting new methods of measuring the ignition or self-heating behavior of materials.

1957—To provide the Quartermaster Corps with guidelines for designing safer military clothing, the Bureau measures static charge generation, a common danger near gasoline or explosive detonators when a soldier is wearing rubber-soled shoes and a nylon-lined jacket over a wool shirt.

1971—NBS-developed standards for surface flammability of small- and full-size carpets and rugs go into effect.

1973—NBS-developed standards for flammability of children's sleepwear (sizes 0-6x) and mattresses go into effect.

FLAMMABILITY:
A NEW LOOK AT AN AGE-OLD PROBLEM

THE ready flammability of materials has been a problem to man since he discovered fire and its uses. Early on, man recognized that adding substances to combustible materials could reduce their flammability. By the fourth century B.C., historians report, people had tried to fireproof wood by treating it with vinegar.

Beginning in the 1700's, attempts at fireproofing became somewhat more sophisticated, but were still largely a matter of trial and error. One of the most notable and successful experiments was carried out by the French chemist and physicist Joseph Louis Gay-Lussac. Following several disastrous European theater fires, he was commissioned by King Louis XVIII to find a way to protect fabrics used in theaters. After studying a variety of substances, Gay-Lussac found that ammonium salts of sulfuric, hydrochloric or phosphoric acid were effective flame retardants for hemp and linen fabric, and he noted improved effectiveness when using a mixture of ammonium chloride and ammonium phosphate.

Today, governments are still interested in protecting consumers against the hazards of fire. The U.S. Government has the responsibility under existing law to assess flammability hazards and has already set flammability standards for such household items as carpeting, mattresses and some children's sleepwear. Standards for other consumer products are presently under consideration. But the study of flame retardants today is still largely an empirical science, not much different than in the day of Gay-Lussac.

Although it is common to treat cotton, nylon and polyester with a variety of flame retardant chemicals such as compounds of antimony, phosphorus and halogens, these treatments are far from perfect as they are not always efficient and must be added in quantities so great that they change the fabric's properties. Many scientists believe that the task of making better flame retardant materials requires an improved understanding of the basic chemical processes involved in retardation.

Molecular Level

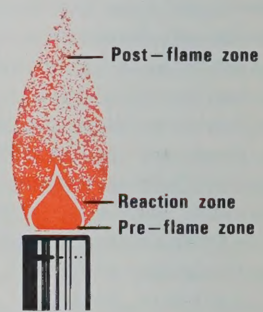
Developing this understanding is the primary objective of flame chemistry research being conducted by scientists at the National Bureau of Standards' Institute for Materials Research (IMR). By studying what happens to flames and flame retardants at the molecular level, IMR scientists hope to learn how currently used flame retardants may be improved and how new ones may be designed.

Dr. John W. Hastie and Carolee McBee, assisted by Arthur B. Sessoms, have been looking at what happens to flame retardants when they are heated and when they are introduced into laboratory flames, using the techniques of mass spectrometry and optical spectroscopy. However, such studies require an understanding of the combustion of a flame-retarded material.

Combustion of a fabric or polymer involves a thermal breakdown of the material, resulting in the formation of flammable gases that enter the flame. These gases then undergo gas phase pyrolysis or oxidation to form reactive chemical species. To understand the chemistry of flames it is important to study the individual species, including hydrogen atoms, which are especially important in flame propagation. Most scientists believe that chemical fire retardants act either by modifying the thermal breakdown process or by releasing active flame inhibitor species to the gas phase. The NBS research currently focuses on the latter mode of retardation.

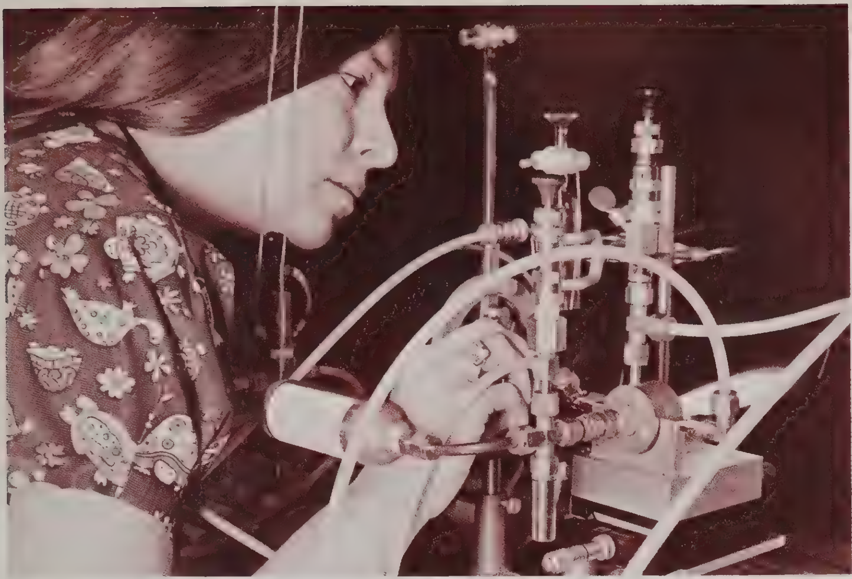
Gas Phase Studies

Using a special high-pressure mass spectrometric system, the IMR group has examined the chemistry of some



typical commercial flame retardants at temperatures corresponding to the decomposition of burning polymers. These vaporization studies included two principal classes of flame retardants; one of these involves the combination of metal oxides with halogen sources while the other is based on phosphorus-containing compounds. They have shown that the metal oxide-halogen systems function through chemical reactions that lead to the formation of volatile halides of elements such as antimony or tin.

Subsequent chemical reactions involving these newly formed species can result in depletion of the system's flame propagating species. In practice, the halogen source is a chlorinated or brominated organic compound incorporated in the polymer. The halogen compound decomposes when the polymer is heated, producing gaseous hydrochloric acid or hydrobromic acid.



In her optical spectroscopic work, Carolee McBee adjusts the burner position prior to taking composition profile data on the flame shown.

Work is also underway on phosphorus-containing compounds, which have also been found to be effective flame retardants, although functioning on a somewhat different principle. Experiments of this type allow the scientists to estimate how much of the active retardant species will be released from the flame retarded polymer and to compare the effectiveness of various flame retardants.

Probing Flames

The next step in understanding the way retardants work is to look at the chemistry of the released retardant species under flame conditions. Using the mass spectrometer, Hastie has studied laboratory methane-oxygen flames in detail. First, he sampled the various regions of the flame—the pre-flame zone, the reaction zone (where most of the important chemical reactions happen) and the post-flame zone. This study gave him a "composition profile" of the flame, that is, the concentrations of various chemical species as a function of location in the flame.

Once a flame is characterized in this way, it can be used as a test system to study what species are produced in the flame when an inhibitor is added and how the presence of an inhibitor affects the chemistry of the flame itself. Hastie's studies of antimony systems, for instance, suggest a very complex chemistry in which antimony species contribute in several ways to flame retardancy.

The mass spectrometric technique developed by Hastie—which allows him to study flames at one atmosphere—is an extremely sensitive tool. However, because a probe is used to sample the flame, there is a possibility that the probe perturbs the flame, and thereby introduces a source of error. To confirm results obtained by mass spectrometry, McBee and Hastie are using an optical spectroscopy set-up which does not disturb the flame under study. To date, McBee has found the same kinds of changes in flame composition profiles as those found by the mass spectrometric techniques for flames with no retardant additives. In the future she plans to look at what happens to these flames in the presence of retardants.

In addition to the mass and optical spectrometric studies of flame radicals and retardant additive molecular species, NBS scientists plan to investigate the role of ions (charged species) in these flames with respect to smoke formation and abatement. Smoke can be one of the major hazardous factors in a fire since it often obscures the route to safety and displaces oxygen in the lungs.

Modeling Flames

Data obtained by Hastie and McBee will be applied to developing mathematical models of flames which can be used to predict what should happen in various flame retardant systems. Another NBS research chemist, Dr. Robert L. Brown, is beginning such a modeling project in conjunction with scientists at the Massachusetts Institute of Technology.

In a related project, other NBS scientists are beginning the study of polymer pyrolysis under inert and oxidizing atmospheres as well as the effects of accelerated aging of polymers on their burning behavior. Data from these experiments will be useful in the development of mathematical-chemical models of flame spread and toxic gas production.

Eventually, modeling studies should greatly improve the ability of scientists to predict what chemicals will make good flame retardants. At present, selection of retardants by industry continues to be, for the most part, a trial and error process, even though based on a considerable amount of experimental data. But, if studies of the sort being performed at NBS succeed in relating the chemistry of retardants to the way in which they reduce flammability, then more effective retardants can be developed.

A fundamental understanding of flames and retardants may also lead to the formulation of treatments that minimize undesirable side effects such as formation of smoke and toxic reaction products. Consideration of such side effects may become crucial if future government standards for reducing the flammability of items become more stringent by including requirements for reducing the production of toxic gases and smoke. □

From Thales to

LIGHT, according to Noah Webster, is the absence of darkness. Though Webster doesn't mention it, light comes in all colors of the rainbow. It also comes in bright, dim and all shades of in-between. There is more light in the summer than in the winter, and since the energy shortage, there is less light at night than there used to be.

Light, the scientists tell us, is part of the same family of phenomena as electricity, radio and television waves, infrared heat, x-rays and some less commonly known rays like gamma and cosmic rays. That concept is hard to verify with the human senses, even though all electromagnetic waves taste, sound and smell the same—like nothing. Light we can see and electricity we can feel, as anyone who has ever stuck his finger in a turned-on light socket will testify. We can also feel heat produced by infrared and use heat lamps on sore muscles or bask in the sun—either of which feels different from electricity! The rest of the electromagnet family is imperceptible to our sensory system.

All of this undoubtedly had something to do with man's being on earth for thousands of years before he got an accurate conception of the nature of electromagnetic waves.

In 600 B.C., Thales of Miletus (Greece) observed that amber, after being rubbed, attracted particles. That was the beginning of understanding electromagnetics. It wasn't until 2,255 years later that James Clerk Maxwell, a Scotsman, developed the theory of electromagnetic waves. He not only theorized that they existed, he developed equations which accurately described their behavior. Thirty-one years later, in 1866, Heinrich Hertz of Germany demonstrated their existence experimentally.

Since then, scientists have proven indubitably (human sensory systems not withstanding) that light, radiated heat, radio, x-rays and some other things are basically the same things—electromagnetic waves.

Though understood for only a little more than 100 years, the study of electromagnetic waves has contributed more to man's scientific understanding of his world and universe than has any other phenomenon. This is true largely because scientists can measure some electromagnetic waves more accurately than they can measure anything else. These measurements provide a basis for accurately measuring both time and distance, a relationship which becomes apparent upon examining the characteristics of electromagnetic waves.

They all travel the same speed in vacuum, approximately 300,000,000 meters per second, or 186,000 miles per second. That's equal to about six laps around the earth in 1 second's time. Also, they travel in waves, with crests and troughs, like water. The distance from crest to crest (or trough to trough) is one wavelength.

Accordingly, wavelengths are short or long depending on their frequency, (the number generated in a given time period). For instance, household electric current is generated at the rate of 60 waves (cycles) per second so its wavelength is the distance it travels in a second, divided by the number of waves or about 5,000,000 meters. Infrared is generated at several trillion times per second and

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JOSEPHSON JUNCTION USED TO MEASURE FREQUENCY

its wavelength is measured in millionths of a meter (micrometers).

Energy is required to generate electromagnetic waves of any frequency. The frequency of an electromagnetic wave is customarily expressed in cycles per second. To further simplify the language of electromagnetics, cycles per second are

Dr. Donald McDonald, NBS physicist, tunes the output from the Josephson junction while watching for the best signal on an oscilloscope.

known as Hertz, in honor of Heinrich Hertz, mentioned earlier. Thus electric current has a frequency of 60 hertz, and infrared about 3,800 billion hertz (or 3,800 gigahertz—GHz).

The third dimension of an electromagnetic wave is its power which is indicated by the height of the wave from crest to trough. Though this may be conceived as a physical dimension, it isn't usually measured as such. Instead, power is measured in terms of the heat it will produce, or an amount of work it will do.

Even a rudimentary understanding of frequency, wavelength and power of electromagnetic waves banishes much of the mystery about them. It explains why we can feel electricity, see light and feel the heat from infrared. It's because our sensory system responds only to certain frequencies. Similarly, a short-wave radio receiver cannot receive AM radio broadcasts, and vice versa.

At frequencies about 100 times higher than infrared, electromagnetic waves are visible as light—the absense of darkness. White light simultaneously contains many or all of the frequencies which the human eye can see. Red light contains only the lower frequencies of the visible spectrum; blue light the highest visible frequencies. Between red and blue are all the other colors of the rainbow with their respective wavelengths. Brightness indicates power and may range from invisible to intolerable to the eye.

Electromagnetic waves, whether light, electricity or radio, are most useful to man when their frequency (and hence wavelength) can be controlled. Such control requires accurate measurement of frequency, and measurement of high frequency is a continuing challenge to scientists at the National Bureau of Standards.

In November of 1972, Dr. Kenneth M. Evenson and colleagues at the

Shown is a Josephson tunnel junction mounted in a 10GHz (X band) microwave guide. At NBS, such junctions are being used to maintain the U.S. legal volt.

NBS Boulder Laboratories amazed the scientific world by accurately measuring the frequency of a helium-neon laser at 88 trillion hertz (88 terahertz or 88 THz). A previously unachievable measurement, it required a battery of six lasers, some very temperamental electronics and several steps of harmonic frequency multiplication from the Bureau's primary frequency standard. It was a scientific breakthrough which led to the most accurate value ever measured for the speed of light.

High-frequency measurements depend on reference standards derived from harmonic multiplication of base standards of frequency. Electromagnetic waves interacting with matter can generate higher frequencies called "harmonics." By definition, the first harmonic is the fundamental frequency, the second harmonic is twice the frequency of the fundamental, the third is three times the frequency of the fundamental and so forth.

continued on page 142

HIGHLIGHTS

Pesticide Technology

To help counteract possible undesirable effects of the Federal Environment Pest Control Act of 1972 on the pesticide industry, the NBS Experimental Technology Incentives Program (ETIP) and the Environmental Protection Agency (EPA) are conducting a joint inquiry to define new incentives that will encourage the pesticide industry to further its research and development programs.

The Act requires that all pesticides be registered with EPA by 1976. At the same time, these pesticides must meet two criteria: (1) they must not be hazardous to human health; and (2) they must not be bioaccumulative.

Calibration Service

NBS Boulder announces a new calibration service for ultrasonic power measuring devices employing water as the coupling medium. Initially, the service will be limited to an operating frequency of 2 megahertz, though NBS standard transducers at 1, 3 and 5 megahertz are being developed. Calibrations will cover the power range from 1 milliwatt to 1 watt and will have an uncertainty of about ±5 percent.

For information contact Thomas L. Zapf, Electromagnetics Division, NBS, Boulder, Colo. 80302.

Optical Radiation

NBS is planning to produce a self-study manual on optical radiation measurements. Work is scheduled to begin in July, and chapters will be issued in a special Technical Note series as they are completed.

The manual will present the basic concepts and apparatus required for accurate and efficient radiometry, photometry and spectrophotometry. This material will then be used to develop a variety of techniques useful for solving present-day problems associated with this measurement area.

High-Rise Building Fires

Since high-rise buildings pose unique fire safety design requirements, NBS has begun smoke movement studies in a prototype modular high-rise building at the Jersey City, N.J., Operation Breakthrough site.

During these studies, NBS will test the performance of such innovative fire safety features incorporated into the building design as ceiling sprinklers in every apartment, detectors in halls that control doors which can be held open by an electromagnet and detectors that sense fire and sound alarms. In addition, NBS will observe the performance of smoke detectors installed in the building and then compare the site test results with those obtained in the laboratory.

Mercury Monitor Calibration

In work sponsored by the National Institute for Occupational Safety and Health, NBS has developed and constructed an apparatus for the accurate generation of test atmospheres of mercury in air, or other diluent gases, at concentrations between 0.005 and 0.500 μg/l. An incoming gas stream is saturated with mercury vapor, then quantitatively diluted to obtain the desired concentration.

The apparatus was developed to calibrate monitors used in measuring the exposure to mercury of workers in industry but covers a much wider range of concentrations. Accordingly, it is useful for checking the performance of instruments as well as to evaluate analytical methods for measurement ranging from ambient to stack concentrations.

Weights and Measures Conference

The 59th National Conference on Weights and Measures will be held in Washington, D.C., on July 7-12, 1974. Weights and measures officials are charged with the duty of protecting the consumer while also assuring fair treatment for producers and distributors. To this end, the conference develops model laws, regulations and codes which, in turn, serve as legal requirements when officially adopted by states, counties and cities.

For information contact Harold F. Wollin, A207 Metrology Building, NBS, Washington, D.C. 20234. Telephone: 301/921-2401.

Food and Nutrition Survey

The Bureau is undertaking a preliminary study of the Women and Infant Children supplemental food program for the Food and Nutrition Service of the Department of Agriculture. The study is concerned with two issues: What are the relative efficiencies of the various methods being used to distribute food packages to low income individuals? And are the foods being offered consistent with the recipient's preferences?

Vote Tallying

The General Accounting Office (GAO) has contracted with NBS to conduct a 1-year study of the use of computers in vote tallying. The Bureau will identify critical factors in successful computer tallying after surveying jurisdictions that have em-

ployed computers in conducting elections as well as State regulations relating to their use. Based on both this experience and on general expertise in computer utilization and security, NBS will develop guidelines that election administrators can implement to help insure the accuracy and security of the vote-tallying process. NBS will also provide information via GAO to election officials about new and forthcoming technological developments involving computers that might be applied to the vote-counting process.

Dr. Arthur O. McCoubrey, new IBS head.

New IBS Head

Dr. Arthur O. McCoubrey, a leader in the development and application of frequency and time standards, was recently named director of NBS' Institute for Basic Standards by NBS Director Dr. Richard W. Roberts. McCoubrey, 54, comes to the Bureau from Frequency & Time Systems Inc., Danvers, Mass., where he served as vice-president and director.

In making the appointment, Roberts said McCoubrey, "Brings to the Institute for Basic Standards and the Bureau a distinguished record in private industry, where he for years has been in the forefront of developments involving precision instruments."

Critical Point of Ethylene

Scientists at NBS have measured the critical temperature and density of ethylene to unprecedented accuracy. This development will permit more accurate PVT tables to be calculated and used for custody transfer purposes.

The critical point is reached at approximately 9° C and 50 atmospheres pressure, a condition similar to that under which ethylene is frequently transmitted and sold in gas lines. Accurate knowledge of the critical point parameters will help create greater confidence in the measurements made when ethylene is bought or sold.

Joint Measurement Conference

Measurement science in transition will be the theme of the 1974 Joint Measurement Conference to be held at the National Bureau of Standards in Gaithersburg, Md., on November 12-14, 1974. The conference is designed to provide an interdisciplinary exchange of technical and managerial measurement concepts in the optical, mechanical, electrical, dimensional and related fields.

The goal of the conference is to define the role and value of measurement to all areas of modern industry and describe the state of transition of measurement science from the laboratory into our everyday lives.

Information is available from Joseph Cameron, A345 Physics Building, NBS, Washington, D.C. 20234. Telephone: 301/921-2805.

Privacy and Security

The proceedings of a conference that highlighted the needs and problems of Federal, State and local governments in safeguarding individual privacy and protecting confidential data in computer systems from loss or misuse have recently been published by NBS. The origin of governmental problems is discussed in the context of the public's concern for privacy arising out of computer-based recordkeeping, the diverse legislative actions now being taken to safeguard privacy, the threats to the security of computer-based information systems and the technological problems associated with protecting against such threats. Major needs are also described.

This publication is available as NBS Technical Note 809 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 85 cents. Order as SD Catalog No. C13.46:809.

Antenna Calibration

A new technique developed at NBS Boulder calibrates the gain and polarization of standard antennas without reference to a known antenna.

The technique consists of two principal operations. First, three unknown antennas are used in a generalized three-antenna measurement of amplitude and phase characteristics as a function of separation distance. Then, the data are rigorously evaluated by a computer to correct for proximity and multipath interference effects. The results provide absolute gain and polarization data on all three antennas. ☐

Effects of Metrication on the U.S. Economy

Excerpts from remarks by Jeffery V. Odom, Chief, Metric Information Office, at a recent Metric Conference in Los Angeles.

IN our 3-year U.S. Metric Study, we attempted to determine the costs and benefits of a change to metric. This was done because everyone wants to know what metrication will cost, and also because the Metric Study Act of Congress directed us "to evaluate the cost and benefits of alternative courses of action." From the start we felt that such costs and benefits would be extremely difficult, if not impossible, to evaluate in dollars and cents. The British have found, both during and after conversion, that such estimates cannot be made because the metrication costs although currently incurred are hard to isolate, while the benefits are largely intangible and continue indefinitely into the future.

In our study we determined that whatever the cost of conversion it will be less if we change by plan rather than haphazardly. We are already slowly drifting to metric; thus our metric costs, whatever they are, are occurring and accumulating. Realistically we do not have the alternative of *not* spending the money, of *not* going metric. Therefore, it is not fair to speak of the cost of metrication and stop there; we must consider that a planned program, although it may incur costs, will lead to an actual net savings for us in the long run. The reason, of course, is the obvious savings that come with careful planning and coordination.

Incidentally, this point is what some of the few remaining metric detractors are completely missing. They worry about the impact of the costs of going metric on our economy –especially in view of the present inflation. Certainly we need to remain aware of such concerns. But even if now is not an ideal time to go metric–and I am making no judgment here–the point is that we **are** going metric **now**. And we can lessen the impact to our economy by acting to hold down the costs. This we can do best by having careful planning of the type that would be provided by legislation now under study by the Congress.

As I have stated, metric usage in the United States is slowly increasing, and it is of first importance to recognize the fact that it is our industry and not our government that is initiating increased metric use. The motivation of the Department of Commerce in sponsoring metric legislation is our desire to do what we can to make the changeover as easy as possible and also as beneficial as possible for the whole country. The objective of all of us should be to reap maximum benefits from the changeover with minimum cost and inconvenience.

Why are we slowly converting? Our industry is more and more finding that increased metric use would be to its economic advantage for two reasons: first, as an aid to maintaining and expanding our exports and, secondly, as a means of avoiding the inefficiency and inconvenience in operations of U.S. plants at home and abroad, manufacturing the same products, to different standards.

As industry changes over to metric, one basic principle is being followed and care should be exercised to see that it continues to be followed. We must insure that we follow the rule of reason–this states that changes to metric should be made where it is advantageous to do so—no areas should change "at any cost," but neither should any area refrain from changing "at any cost."

An NBS study shows that the main impact of metric conversion on the building industry will be in administrative areas.

This common-sense approach to metrication takes the very foundation out from under the estimates of as high as 50 or 100 billion dollars that have appeared in print. I would suggest that if such cost estimates have validity, most of the types of changes that contribute to those cost estimates will not be made and that the changes that will be made will pay for themselves.

None of us belittles the magnitude of the metrication process. It will mean that, to the extent we use weights and measures, we will all have to learn to "think metric." We must also minimize potential confusion during the transition period.

Presently the increase in metric use in the United States is proceeding in a haphazard and unplanned way, with individual companies making the changeover when each deems it advantageous to itself to do so. The changeover should be synchronized so that metric standard parts and materials are available on schedule at the time when these items are scheduled to be incorporated in machinery and devices of all types in which they are components. This synchronization can come only from careful planning—on an economy-wide basis. This synchronization and planning will be helpful to all of our industry as it changes over to metric, but they will be of greatest benefit to "small business" because, unlike our industrial giants, small companies do not, in general, have extensive means for company planning and should have the benefit of national planning.

Although we do not know what the total cost of metric conversion would be, there is no urgent necessity for having this interesting piece of information provided that we follow the cost avoidance or cost recoverable course to which I have alluded. There is a consensus that by following a carefully planned voluntary program to guide the changeover now underway, we can avoid any major negative impact on our economy. Further, while we minimize costs now already committed to be spent, we must be alert to opportunities to achieve all possible benefits, such as rationalization of sizes and increased foreign trade. Thus, the changeover to metric can be expected to have a positive impact on our economy. □

Metrication and the Housing Industry

A recent study by Robert G. Hendrickson and Donald W. Corrigan, both of the NBS Technical Analysis Division, presents "An Overview of the Factors Impacting Metrication of the U.S. Housing Industry."

The survey, sponsored by the Department of Housing and Urban Development, found that the essential impact of metric conversion will be in its administration rather than its technical implementation. It appears that problems of adapting codes and standards, sustaining dual inventory costs and contractual negotiations will be far more dominant than the problems of technology conversion, quality control or product performance criteria.

According to this report, the redefinition or accomodation of the 15,000 local building codes and the coordination of the more than 100 sources of building standards in the United States to define, develop and implement standards consonant with metrication pose the biggest problems for this industry.

The objective of the NBS study was to identify probable major problems associated with the conversion of the domestic United States housing industry to the metric system of measurement and the manufacture and use of products based on metric dimensions and standards. Information on problems of conversion was sought from other countries with metric experience. Opinions expressed by participants in the Construction Conference, held as part of the U.S. Metric Study effort, were included in the survey.

The five major items of concern in order of importance to the participants of the conference were costs, training, standardization, on-site adaptation and industry coordination. Most problems are expected to occur across a wide range of activities with varying degrees of impact. However, these responses were made by persons not actually going metric under an official program but are perceptions of problems in a hypothetical situation.

Hendrickson and Corrigan have evaluated these items in light of the experiences of other countries undergoing metrication. The following is a summary of their findings.

Any action taken by a company or individual over and above his normal operating procedures to convert to metric represents a direct or indirect cost either to himself, or eventually to some other party. It is not surprising therefore, that cost headed the list of problems. To some, the cost is less important than to others, but in no case is cost expected to be critical.

Training was the second most frequent problem indicated, based most likely on its universal impact upon every phase of housing tectonics and

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administration. The British concern about training problems of the middle-aged and staunch believers in imperial units was unfounded in actual practice. This aspect of conversion to metric should present the least problem to companies, although training programs will involve minor costs.

The matter of standardization is a complex issue. It involves what the standard is, how it is developed, whether it is mandatory or voluntary, how widely it applies, the number of standards-setting organizations involved and the direct or indirect impacts on segments of the industry. The magnitude of this situation is clearly drawn when it is realized that over 100 different sources of building standards in the United States for building construction must be brought together in a common effort to develop, approve and implement standards for the adoption of, or accomodation to, the metric system. However, this presents a unique opportunity to achieve uniformity in building codes.

Certainly not all parts of the 15,000 local codes in the United States would have to be changed, but changing those parts dealing with the joining of components, the joining of essentially different functional products and required performance criteria are likely to produce delay, confusion and inconvenience if not adequately considered by the industry prior to conversion. The principal task then lies in developing the standard, obtaining industry-wide concurrence and acceptance and assuring fairness to all parties directly or indirectly affected by the standard.

Industry coordination was seen by the participants to be an essential ingredient to any program of conversion. Without it, the problems of standards, efficiency and timeliness, if not properly anticipated, will probably result in chaos, disorder and losses. □

NBS Develops Nitric Oxide Monitor

A new technique to improve the accuracy of industrial and automotive air pollution detection devices has been developed by Drs. Frederick P. Schwarz and Hideo Okabe, research chemists at the National Bureau of Standards.

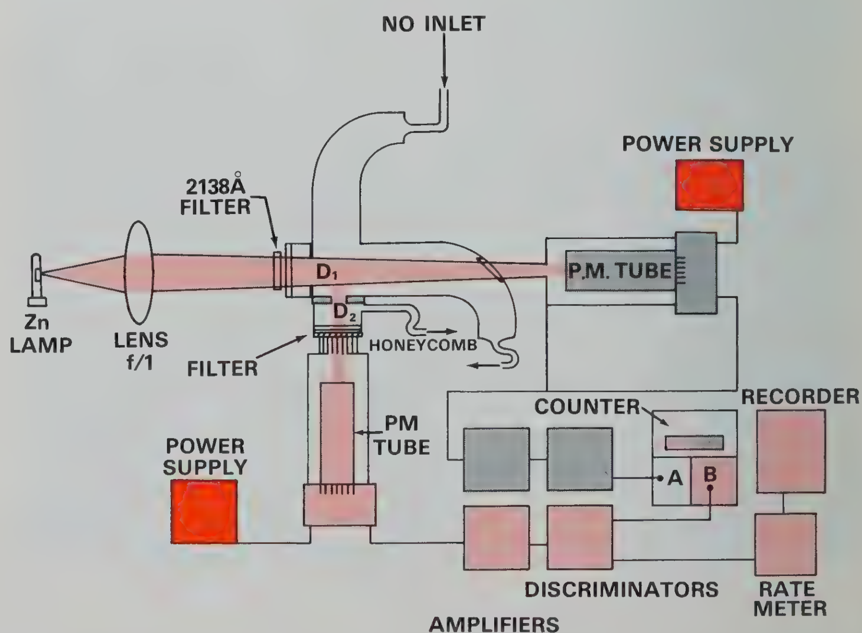
The fluorescence technique, which measures nitric oxide (NO) in nitrogen at levels of subparts per million, was described by Schwarz recently at the national meeting of the American Chemical Society in Los Angeles.

The method will be used to guarantee that the composition of standard mixtures of nitrogen is accurate. These mixtures—which must be calibrated periodically to insure sample integrity—will be offered as Standard Reference Materials (SRM's) by NBS for more accurate calibration of NO detectors throughout the United States. The SRM's will also help insure that measurements of NO taken by different Federal, State and local government agencies and by industry are compatible.

Millions of tons of nitric oxide are released into the atmosphere each year by industrial and automotive sources. Although NO itself is only moderately toxic, it reacts in the air to form nitrogen dioxide which causes respiratory illness when it is present in air at levels of subparts per million and forms hazardous photochemical smog.

Development of SRM's and accurate methods for measuring industrial and automotive air pollutants is a cooperative effort by the NBS Measures for Environmental Quality Program and the Environmental Protection Agency. Accurate measurements of air pollutants, such as NO, are necessary for a more fair and effective implementation and enforce-

Schematic of nitric oxide monitor.



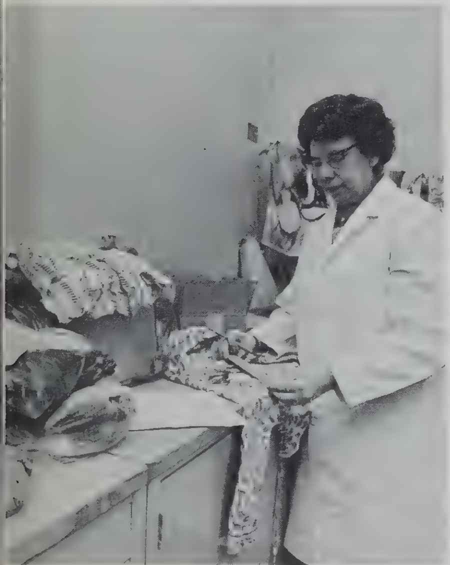
ment of the Clean Air Amendments of 1970 which limit the amount of pollutants that may be emitted by industrial stacks and automotive exhausts.

The new measurement technique itself can be used as the basis for an accurate, fast and simple air pollution detection device for measuring NO in industrial stack gases and, with several modifications, for measuring NO in automobile exhausts. A patent application has been filed for these purposes.

The method is based on measurement of the intensity of NO fluorescence excited by ultraviolet light of wavelength 2138 Å from a zinc discharge lamp. Using various concentrations of NO in nitrogen, the NBS chemists established that the fluorescence intensity varies linearly with the NO concentration from about 0.04 parts per million to 10 parts per million and sublinearly with NO concentrations up to 300 parts per million.

The new method of detecting nitric oxide is simpler than the widely used chemiluminescent method for NO measurement in which ozone is generated and reacted with NO to produce fluorescing nitrogen dioxide molecules. □

Case histories of fabric fire accidents are compiled and maintained in the Bureau's Flammable Fabrics Accident Case and Testing System.



Latest Publications on Fire Research

OCCUPANT SAFETY IN BUILDING FIRES
Arthur I. Rubin and Arthur Cohen

Fire safety in buildings is important in building design and the formulation of codes and standards. However, an examination of the information concerning the **needs** of occupants in fire emergencies (as opposed to ensuring a degree of structural integrity for the building) indicates that the scientific information base is woefully inadequate. The increasing prominence of high rise buildings having many occupants intensifies the need for better information about the behavior of occupants during fire emergencies.

Fire researchers have indicated that it is often not feasible to evacuate buildings because of time constraints. Instead, designers use techniques such as safe areas within buildings that require people to respond differentially, based on their particular location. This approach emphasizes communications and warning systems to transmit messages. These systems, such as loud noises or blinking lights, should be designed to "take advantage" of the usual responses made by people. Occupants should be a part of the fire warning and fighting system. The authors pursue this possibility and take a human factor approach to suggest some means of better understanding the capabilities of occupants.

FIRE ACCIDENTS INVOLVING SLEEPWEAR WORN BY CHILDREN AGES 6-12
James A. Slater

Sleepwear was the first fabric item ignited more frequently than any other item in over 1,900 fire incidents reported to the National Bureau of Standards Flammable Fabrics Accident Case and Testing System (FFACTS). Information acquired since promulgation of the current sleepwear flammability standard protecting children of ages 0-5 indicates a problem of comparable magnitude exists for children of ages 6-12. Of 316 incidents involving non-contaminated sleepwear that was first to ignite, about one-fourth involved children 0-5 years old and one-fourth involved children 6-12 years old.

For the 6-12 group, sleepwear ignited first more often than all other garment items combined. Females outnumbered males 4-to-1 in the 6-12 group, due mostly to the involvement of nightgowns and kitchen ranges, the most common ignition source for this age group. Five of the 6-12 year old children died and 52 of 74 victims were hospitalized. Almost all of the first-to-ignite sleepwear in this group was cotton. Data from Shriners Burns Institute and the National Burn Information Exchange provide further evidence of the involvement of children ages 6-12 in garment fires. It is recommended that a new standard be issued covering sleepwear sizes 7 through 14 to effectively protect 6-12-year-old children.

FIRE ACCIDENTS INVOLVING THE IGNITION OF SLEEPWEAR WORN BY CHILDREN UNDER THE AGE OF THREE
Elaine A. Tyrrell

Accident case histories of children under age 3 involved in sleepwear fires are examined in detail. Of 434 persons involved in sleepwear ignition incidents in the NBS Flammable Fabrics Accident Case and Testing System as of January 1973, 101 were children under age 6; 22 of these were children under age 3. In 15 of

turn page

these 22 accidents, the child was a victim of his own actions, while in 7 more accidents, the child played a passive role in the ignition sequence. Matches and kitchen ranges were the most frequent ignition sources found for this group of children. Seven of these small children died; the remaining 15 victims sustained burn injuries covering from 1 to 65 percent of their bodies.

Most of the sleepwear items involved in these 22 incidents were made of cotton and 14 of these 22 items were pajamas. Children under age 3 were most frequently involved in fire accidents during the morning hours in the kitchen or bedroom. Only one child was under the supervision of an adult at the time of the accident. From the information found in the case history reports, an analysis of the severity of the injuries received by the victims was made and it was determined that the severity of the injuries received by one of the three infants under the age of 1 and 15 of the remaining nineteen 1- and 2-year-olds probably would have been reduced if they had been afforded the protection of a flammability standard.

KITCHEN RANGES IN FABRIC FIRES

Allan K. Vickers

Kitchen ranges played a major role in the 1616 fabric accident case histories recorded in the Flammable Fabrics Accident Case and Testing System as of May 1972. They accounted for 214 or 35 percent of the direct garment ignitions in FFACTS. Female victims outnumbered males by 3 to 1; females under 16 and over 65 were particularly heavily represented. Reaching over and leaning against the range caused the majority of the garment ignitions. Shirts, robes, pajamas, nightgowns and dresses were the most frequently ignited garments. Thirty-four victims died from injuries resulting from garment ignitions from ranges; 24 of these fatalities were people over 65 years old. □

New Ultraviolet Machine Will Outshine the Sun

WORK that will increase the amount of ultraviolet radiation available at the National Bureau of Standards for experimental purposes by as much as 100,000 times is currently underway.

In a paper presented at the Washington meeting of the American Physical Society, Drs. Robert P. Madden and David L. Ederer of the NBS Far Ultraviolet Physics section described the work being done to convert the existing NBS electron synchrotron into a much more powerful source of ultraviolet radiation. Completion of the facility is expected in about 4 months.

The extreme ultraviolet (XUV) radiation from the new machine will be more intense than that which would be received on the earth from the sun if the earth's atmosphere did not absorb it. Compared with radiation from the previous NBS synchrotron, the ultraviolet radiation from the new source will be at least 100 times more intense throughout the broad range of wavelengths it emits. In parts of the XUV spectrum, the radiation will be nearly 100,000 times stronger.

The new Synchrotron Ultraviolet Radiation Facility, SURF-2 for short, will be adapted to research projects of many kinds in physics, chemistry and engineering that will be conducted by guest workers as well as NBS staff. It is expected to be particularly useful in such areas as solid state physics, radiation damage in various substances including those of biological origin, optical properties of materials, surface properties, atomic and molecular energy levels and improved measurement methods for ultraviolet wavelengths and radiation intensities.

Construction of the new facility involves converting the present NBS synchrotron (SURF-1) into a storage-ring synchrotron in which a narrow beam of electrons races around a highly stable circular orbit at nearly the speed of light. Each electron, as it speeds through the ultra-high vacuum of the synchrotron's dough-nut-shaped tube, emits radiation concentrated mainly in the forward direction.

The radiation from the electron is produced as they are continually bent away from a straight path into a circle. The force that bends them into the circular path arises from their interaction with a strong magnetic field that cuts vertically down through the horizontal plane of the circle.

Among the advantages of the new facility are: (1) it covers continuously a broad range of wavelengths, (2) its radiation is highly plane polarized and (3) its intensity can be accurately determined.

In the last few years, extreme ultraviolet radiation has assumed a position of importance in experiments on controlled nuclear fusion energy sources, in the fabrication of miniaturized electronic circuits and in other advanced industrial and scientific research areas.

Ordinary microscopes are becoming inadequate because they cannot distinguish details smaller than the wavelength of the light used. "With XUV, we can detect details 10 to 100 times smaller, because XUV, wavelengths are that much shorter than ordinary light waves," Ederer stated.

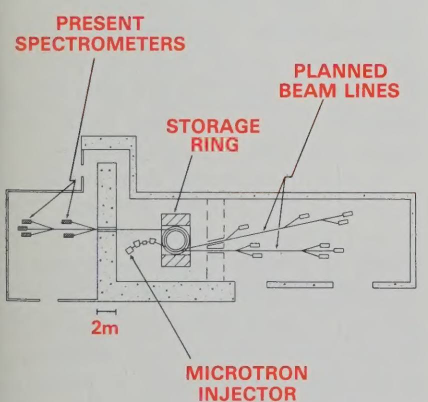
Ultraviolet beams, Ederer indicated, will also be used as probes to explore the surface characteristics of solid-state materials used in minia-

turized circuits. And similar surface studies are needed to solve problems in chemical industries, where surface properties often have an important influence on chemical reactions.

"Besides the surface studies," Madden pointed out, "XUV has other recognized potential applications in the control of chemical reactions and in biomedical manipulations. When XUV rays are absorbed, they transfer enough energy to ionize or break up individual molecules. By tuning to the proper XUV wavelength it should be possible to break up molecules in a predictable way or energize particular parts of the molecule. We could then promote desired chemical reactions or break up undesired living cells, possibly in cancer therapy."

The NBS scientists emphasized that many of these new developments could not be undertaken in the past because sufficiently powerful ultraviolet sources were not readily available. "The big news here," Ederer stated, "is the fact that U.S. technology is now moving rapidly in the development of XUV lasers and laser-related sources of high power. Intensity measurements and other data relating to laser parameters, which we should obtain with the help of the new NBS synchrotron, will contribute to the successful perfecting of these sources." □

New NBS Synchrotron Ultraviolet Radiation Facility.



Validation of Environmental Data

Excerpts of a speech given by John K. Taylor, Chief of the NBS Air Pollution Analysis Section, at the recent national meeting of the American Chemistry Society.

ACCURATE methodology, adequate calibrations and systematic quality control procedures are required to provide reliable analytical data. These three factors may be considered as links in a chain that is only as strong as the weakest segment.

Well-established measurement processes are conventionally established by deliberate or evolutionary processes but environmental analysis has weak foundations in each of the three areas. The rapid growth of this field, both in the number of analyses required and in the variety of substances that must be controlled or measured to evaluate their actual or potential environmental impact is largely responsible for this situation.

The situation needs to be rectified by a systems approach that assures the validity of the data reported by individual stations and permits its incorporation into the body of data derived from diverse sources.

Methodology

The analytical method used for environmental measurements is obviously of prime importance. In the traditional areas of air and water analysis, reliable methods exist to a large extent. However, the explosive expansion of environmental concern has resulted in the need to analyze for many new substances and their degradation products. Also the possible long-term chronic effects of small dosages of almost anything, including many substances ordinarily considered innocuous, has overtaxed the capacity of analytical chemists to make the measurements and has often out-moded conventional techniques. Accordingly, sophisticated trace analyses are often made by unprepared technicians, using methods hastily contrived or borrowed from other disciplines, or in any event of unproven reliability.

The best method for development and evaluation of analytical methodology (and also for development of analytical expertise) is the time-consuming, evolutionary process of research, documentation in the literature and critical examination by peers. A shorter and less adequate route is that of collaborative testing.

The importance of a well-informed statistical analyst in planning and evaluating collaborative studies cannot be over emphasized. A meaningful exercise is best planned by an analytical chemist with broad experience in the philosophy of analysis, detailed experience in the analytical measurement area and familiarity with the particular measurement under study, in collaboration with a qualified statistical analyst with at least some smattering of the above prerequisites. The objectives desired for realization should be clearly understood by both.

Calibration

Adequate calibration techniques are essential to modern environmental analyses which rely heavily on instrumental techniques. Earlier wet methods were essentially absolute in that the substance of interest was often directly measured. In other cases a primary substance, such as pure iodine, for example, was readily available for calibration purposes. The trend toward instrumental techniques has markedly changed this situation in that calibrants closely resembling the system to be measured are required. As a result, the calibration reliability is wholly dependent upon

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VALIDATION *continued*

the quality of the calibrants available. Unless the supplier has endeavored to provide traceability to national standards, by way of Standard Reference Materials, for example, each instrumental measurement might be made with respect to a different reference standard.

Standard Reference Materials as provided by the National Bureau of Standards can play an important role in validating analytical data. Because they are available to all users, they can provide a traceability of all measurements to a common basis.

The confidence that can be placed in calibration materials is a question upon which there are mixed opinions. As a result it is advisable that each laboratory have a means to verify the composition of the materials that it uses. Cross checks with sister laboratories through exchange of materials as well as internal cross checks are means to accomplish this purpose.

Quality Control

Well-developed quality control programs in each laboratory are essential to the production of reliable analytical data. An adequate quality control procedure will not only indicate errors of measurement but will detect departures from control before serious problems have arisen. For best results, control samples should be equivalent to actual samples and as inconspicuous as possible so that they do not receive preferential treatment. Moreover, there must be rapid information retrieval on such samples if corrective measures are indicated.

Quality control measures apply to many areas of analysis, other than the actual measurement process. Record keeping, development of and adherence to time schedules where needed and routine laboratory operations must be monitored. Special checks should be interjected when a change in procedure such as the use of a new supply of a span gas occurs.

Intercalibration

When intercomparibility of data is required for regulatory action or for contribution to a data bank for example, it is essential that a system for intercalibration of laboratories is operative. Although each laboratory may employ reliable methods and scrupulously adhere to valid calibration and quality control procedures, the chance for systematic errors requires a means to intercompare performance.

The identification of inproficiency will depend upon the availability of reliable test samples and their ethical use. It would appear that any organization, including regulatory agencies, requiring interaction with a group of laboratories, should feel a responsibility to periodically provide such a mechanism for intercalibration. Self-examination procedures of the individual laboratories will minimize the need for frequent intercalibration exercises. □

THALES *continued*

Thus, harmonics provide a method of generating higher frequencies in exact multiples of the fundamental. Since the harmonic's frequency is a precise multiple of the fundamental, it can be used as a standard for determining the frequency of an unknown electromagnetic wave of similar frequency. The unknown frequency need not be exactly the same. If it is approximately the same, the two frequencies when mixed together will produce a "beat" or third electromagnetic wave with a frequency exactly equal to the difference between the harmonic and the unknown. Accordingly, the unknown frequency is equal to the harmonic plus (or minus) the beat frequency.

Categorically speaking, the most desirable generator for measuring high frequencies is the one which produces the most harmonics. In the Evenson experiment, the 12th harmonic from a tungsten catwhisker-on-nickel diode was the highest useable reference frequency. This in turn was used to establish a new fundamental with the same frequency, which was then multiplied harmonically to establish a new fundamental, and then this "step" process was repeated.

Recently a group of NBS scientists, Donald G. McDonald, Alan S. Risley, John D. Cupp, and a University of Colorado Electrical Engineer, J. Robert Ashley, developed a superconducting generator using a device called a Josephson Junction to do a similar kind of harmonic frequency generation but with fewer steps. The Josephson Junction is a device theoretically predicted by Englishman Brian Josephson in 1962, demonstrated in 1963 and responsible for one-half of the Nobel Prize for Physics going to Josephson in 1973. It operates at near absolute zero (—273° C or —460° F) and produces many more harmonics than previous generators. As a result, McDonald's team has used, not the 12th, but the 401st harmonic as a reference frequency! With this reference, they were able to measure the frequency of an infrared laser.

In one step, using the Josephson Junction generator, they went from the fundamental frequency of 9.5 GHz to 3,800 GHz! To scientists trying to measure high-frequency electromagnetic waves, that's as exciting as a raise in pay. It is not only more efficient but potentially more accurate because of fewer steps.

To the non-scentist, it will make a difference too, but not this year. The system is still too esoteric to fit the needs of a work-a-day world of engineered electronic systems. Nevertheless, it does promise to simplify, eventually, many of our problems, especially those related to making lasers more useful—albeit by complicated electronics. □

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